



US009156351B2

(12) **United States Patent**  
**Hasewend et al.**

(10) **Patent No.:** **US 9,156,351 B2**  
(45) **Date of Patent:** **Oct. 13, 2015**

- (54) **POWER TRANSFER DEVICE WITH LOW EFFORT MODE SHIFT SYSTEM**
- (71) Applicant: **Magna Powertrain Inc.**, Troy, MI (US)
- (72) Inventors: **Wolfram E. Hasewend**, Graz (AT);  
**Thomas E. Braford**, Brighton, MI (US);  
**Matthew Girlando**, Skaneateles, NY (US)
- (73) Assignee: **Magna Powertrain, Inc.**, Concord, Ontario (CA)
- (\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 94 days.

- (21) Appl. No.: **13/915,687**
- (22) Filed: **Jun. 12, 2013**

(65) **Prior Publication Data**  
US 2013/0337951 A1 Dec. 19, 2013

**Related U.S. Application Data**  
(60) Provisional application No. 61/659,040, filed on Jun. 13, 2012.

(51) **Int. Cl.**  
**B60K 23/08** (2006.01)  
**B60K 17/344** (2006.01)  
**F16D 23/06** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **B60K 23/08** (2013.01); **B60K 17/344** (2013.01); **F16D 23/06** (2013.01); **Y10T 74/19074** (2015.01)

(58) **Field of Classification Search**  
CPC ..... B60K 23/08; B60K 17/34; B60K 17/344; F16D 23/06  
USPC ..... 180/233, 247; 192/38, 54.52, 69.5, 200  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,641,734	A *	2/1987	Muller et al.	192/53.32
4,721,194	A	1/1988	Frost	
4,770,280	A	9/1988	Frost	
4,846,010	A	7/1989	Fujikawa et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

DE	102010039445	A1	2/2012	
EP	698748	*	2/1996	F16D 23/06

(Continued)

OTHER PUBLICATIONS

International Search Report, Sep. 5, 2013, 5 pages.

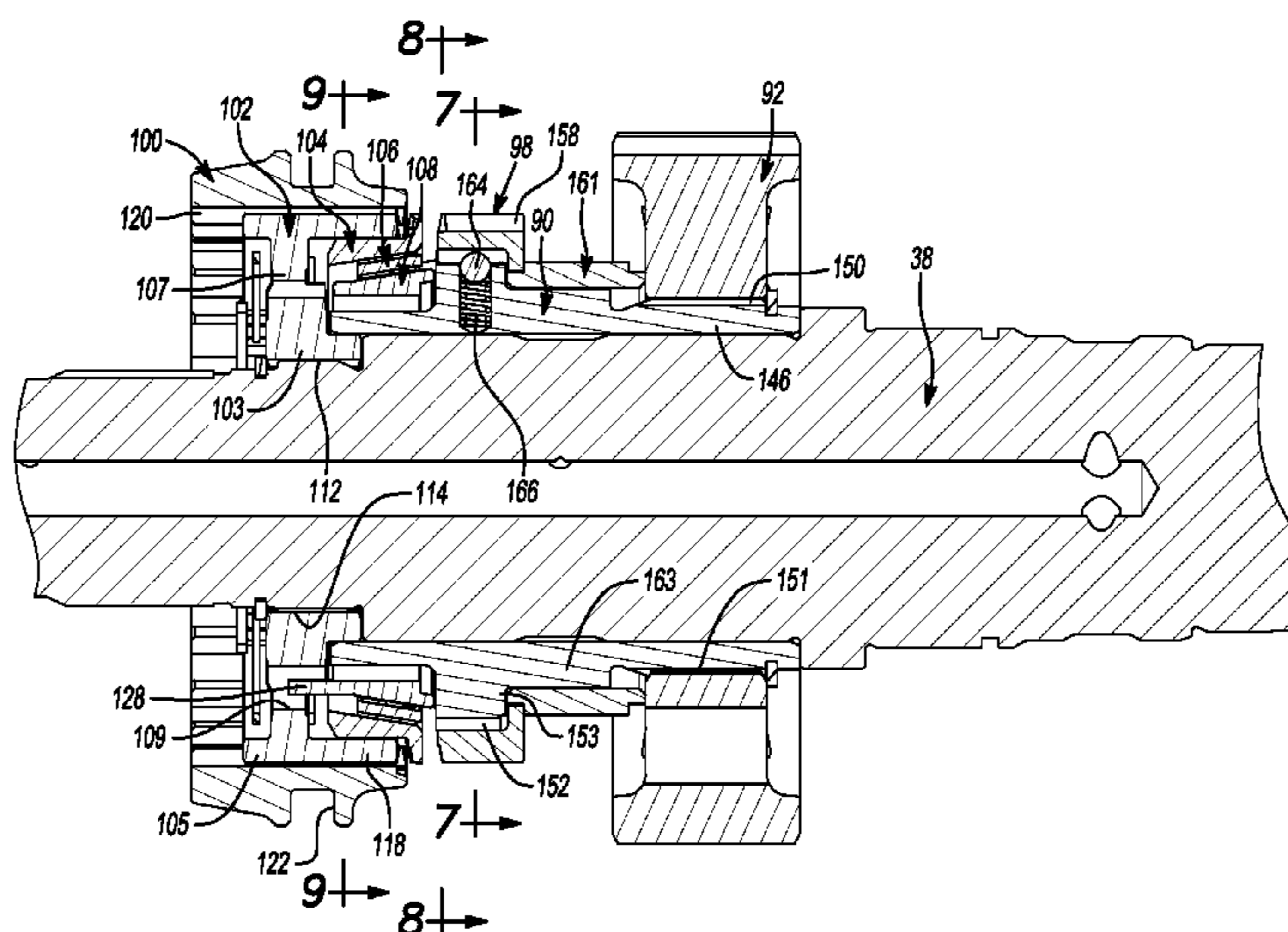
(Continued)

*Primary Examiner* — Joseph Rocca  
*Assistant Examiner* — Maurice Williams  
(74) *Attorney, Agent, or Firm* — Dickinson Wright PLLC

(57) **ABSTRACT**

A power transfer device for a four-wheel drive vehicle includes a first shaft for transferring torque to a first driveline, a second shaft for transferring torque to a second driveline, and a transfer mechanism driving the second shaft. A mode clutch assembly drivingly connects the first shaft to the transfer mechanism and includes a clutch gear driven by the transfer mechanism and a mode sleeve. A sprocket hub associated with the transfer mechanism has external drive teeth meshed with internal drive teeth on the clutch gear with a predetermined amount of backlash therebetween. A ball cam mechanism centers the backlash and permits relative rotation between the transfer mechanism and the mode sleeve to circumvent a blocked mode shift.

**22 Claims, 7 Drawing Sheets**



(56)

References Cited

U.S. PATENT DOCUMENTS

5,076,112 A 12/1991 Williams  
 5,443,426 A \* 8/1995 Frost ..... 475/91  
 5,613,587 A 3/1997 Baxter, Jr.  
 5,699,871 A 12/1997 Hara et al.  
 5,713,243 A 2/1998 Williams et al.  
 5,782,331 A \* 7/1998 Bailly et al. .... 192/53.32  
 5,794,738 A \* 8/1998 Forni et al. .... 188/71.9  
 5,992,592 A \* 11/1999 Showalter ..... 192/43.1  
 6,056,666 A \* 5/2000 Williams ..... 475/320  
 6,071,207 A 6/2000 Stephens et al.  
 6,079,535 A 6/2000 Mueller et al.  
 6,409,000 B1 \* 6/2002 Itoh et al. .... 192/39  
 6,557,680 B2 \* 5/2003 Williams ..... 192/27  
 6,572,506 B2 \* 6/2003 Williams et al. .... 475/204  
 6,579,204 B2 6/2003 Brown et al.  
 6,619,153 B2 9/2003 Smith et al.  
 6,814,682 B2 11/2004 Spitale  
 6,896,087 B2 \* 5/2005 Korenjak et al. .... 180/292  
 6,926,111 B1 \* 8/2005 Irikura ..... 180/234  
 6,974,400 B2 \* 12/2005 Williams ..... 475/198  
 7,004,875 B2 \* 2/2006 Williams et al. .... 475/198  
 7,101,304 B2 9/2006 Swanson et al.

7,124,867 B2 \* 10/2006 Matsufuji et al. .... 192/3.58  
 7,229,378 B2 6/2007 Mueller et al.  
 7,506,559 B2 3/2009 Swanson et al.  
 7,611,414 B2 11/2009 Mueller et al.  
 8,267,235 B2 9/2012 Burns et al.  
 8,307,731 B2 11/2012 Burns et al.  
 8,459,149 B2 \* 6/2013 Suzuki ..... 74/665 GE  
 8,662,270 B2 \* 3/2014 Lee ..... 192/38  
 2003/0092528 A1 5/2003 Williams  
 2004/0198548 A1 10/2004 Showalter et al.  
 2005/0288149 A1 \* 12/2005 Kuhstrebe et al. .... 477/97  
 2007/0278061 A1 \* 12/2007 Wittkopp et al. .... 192/43.1  
 2010/0089685 A1 4/2010 Quehenberger et al.  
 2012/0178575 A1 7/2012 Mueller et al.

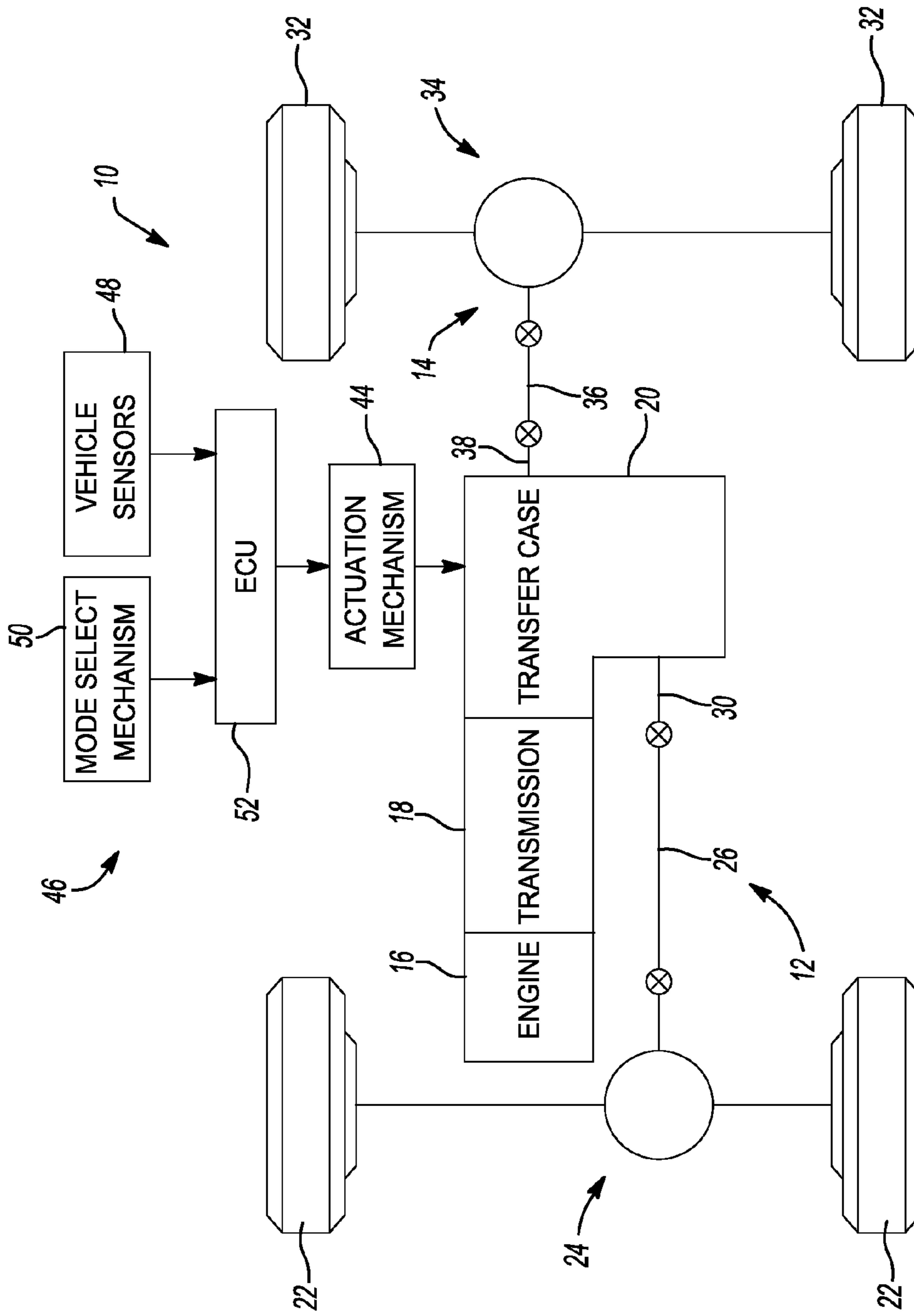
FOREIGN PATENT DOCUMENTS

GB 403319 \* 12/1933 ..... F16D 23/06  
 GB 899349 \* 6/1962 ..... F16D 23/06  
 WO 2008115370 9/2008

OTHER PUBLICATIONS

Written Opinion, 4 pages.

\* cited by examiner



**Fig-1**

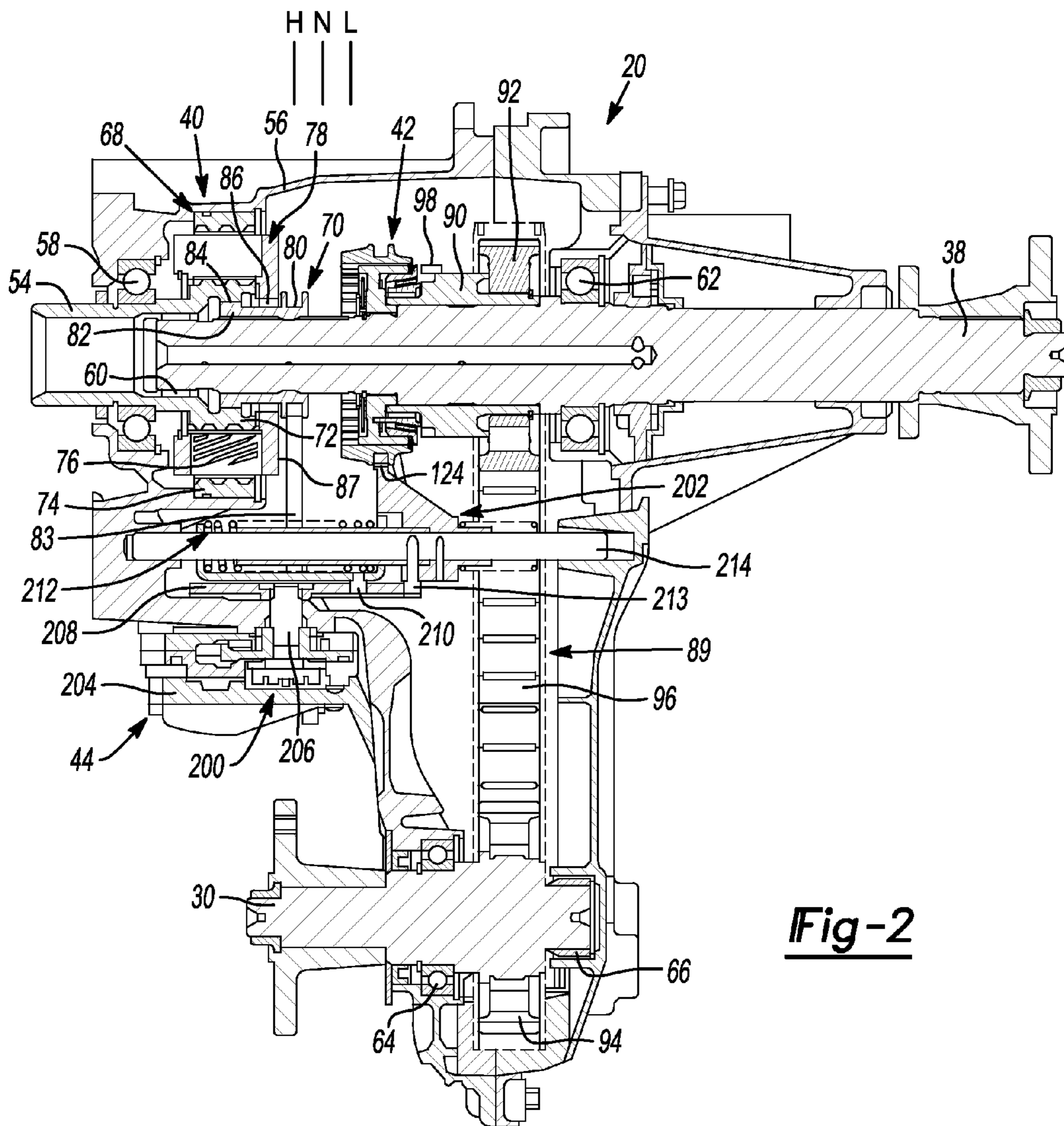
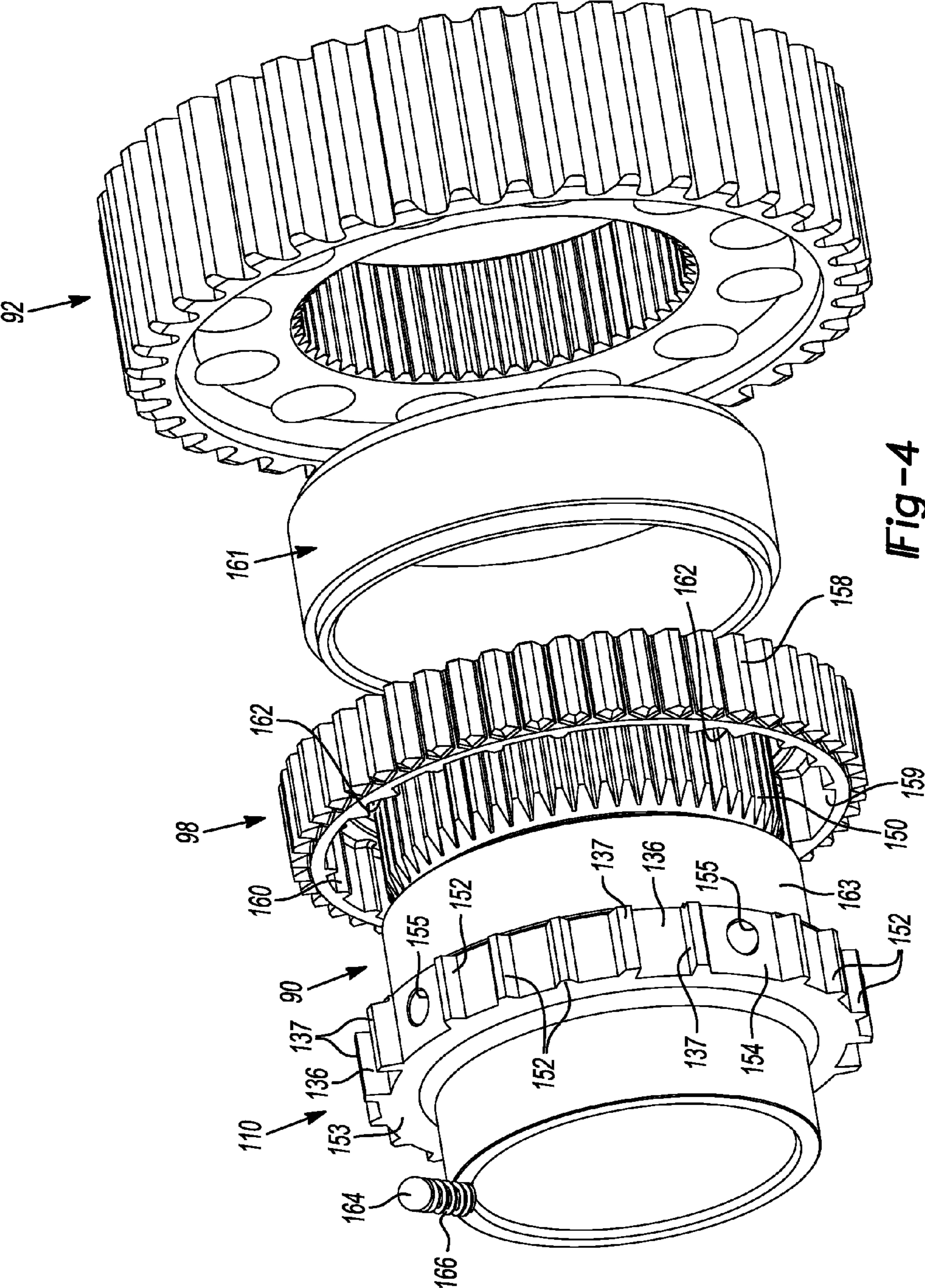


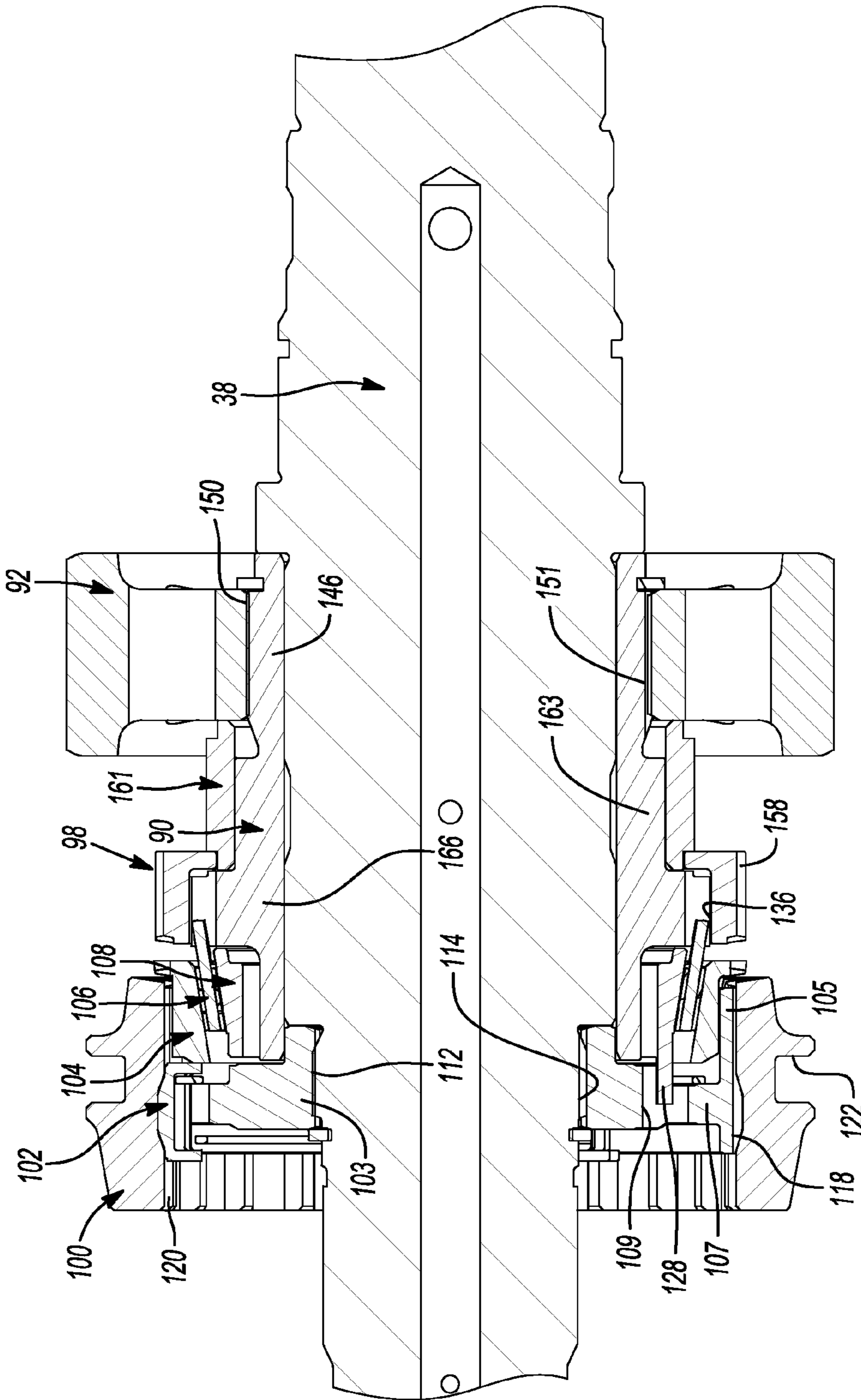
Fig-2





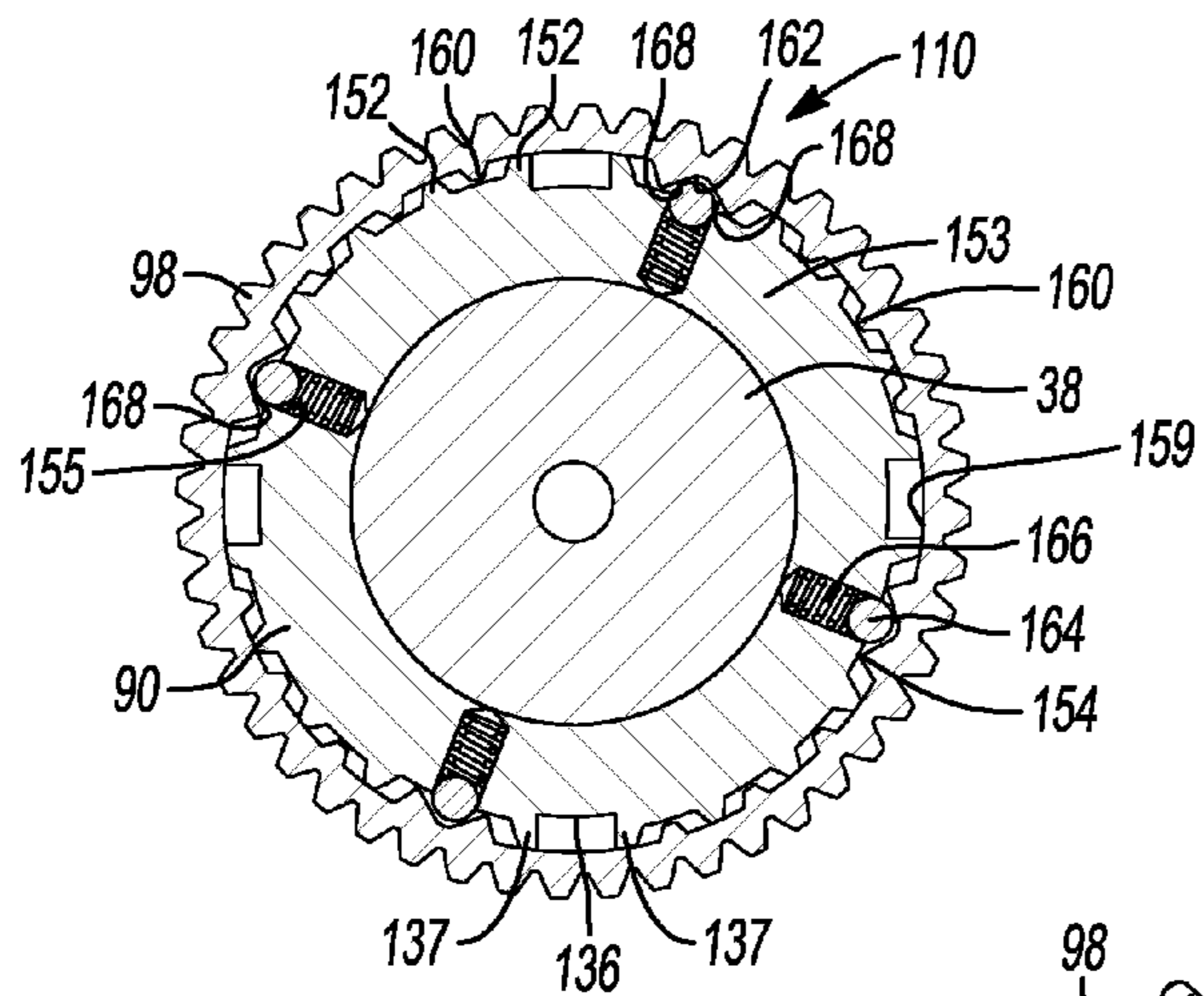
**Fig-4**



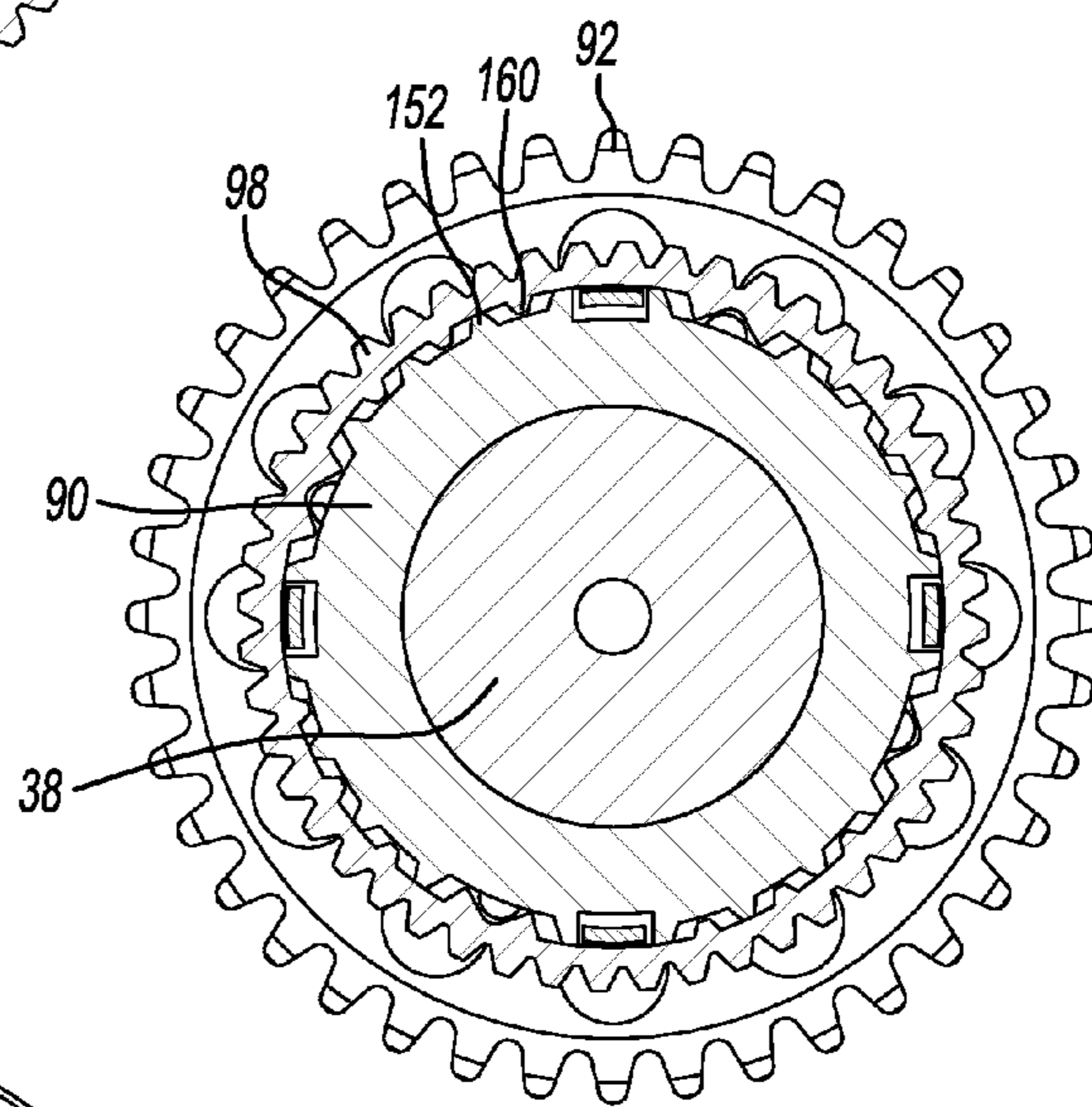


**Fig-6**

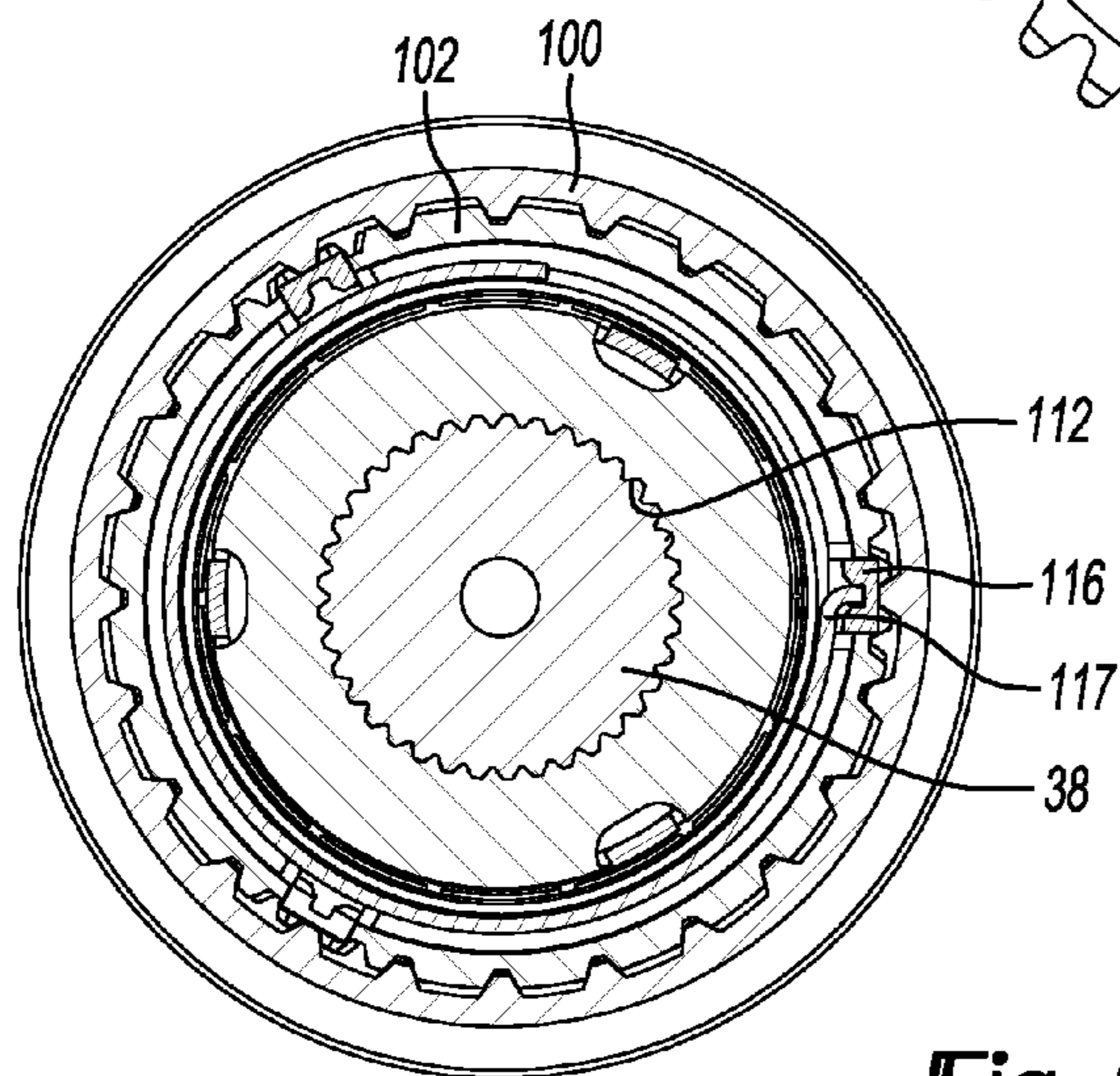




**Fig-7**



**Fig-8**



**Fig-9**

1

## POWER TRANSFER DEVICE WITH LOW EFFORT MODE SHIFT SYSTEM

### CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/659,040 filed Jun. 13, 2012. The entire disclosure of the above-noted application is incorporated herein by reference.

### FIELD

The present disclosure relates generally to power transfer systems equipped with a power transfer device for controlling the distribution of drive torque between the primary and secondary drivelines of a four-wheel drive vehicle. More particularly, the power transfer device is provided with a reduced effort mode shift system for selectively shifting between a two-wheel drive mode and a four-wheel drive mode.

### BACKGROUND

This section provides background information related to the present disclosure which is not necessarily prior art.

Based on the popularity of four-wheel drive vehicles, a number of different power transfer systems are presently available for selectively directing power (i.e. drive torque) from a powertrain to all four wheels of the vehicle. Typically, the powertrain transmits drive torque to a first or primary driveline for driving a pair of primary wheels. The power transfer system includes a power transfer device arranged to continuously or selectively transmit a portion of the drive torque to a second or secondary driveline for driving a pair of secondary wheels. In particular, some power transfer devices are equipped with a mode shift mechanism including a mode clutch that can be selectively actuated to shift the motor vehicle between a two-wheel drive mode and a four-wheel drive mode. In the two-wheel drive mode, the mode clutch is released and drive torque is only transmitted via the primary driveline to the primary wheels. In the four-wheel drive mode, the mode clutch is engaged and drive torque is additionally transmitted via the secondary driveline to the secondary wheels.

Many power transfer devices, such as transfer cases and power take-off units (PTU), are equipped with a mode shift mechanism having a sliding sleeve-type mode clutch to facilitate mode shifting when the motor vehicle is moving or at rest. Such sleeve-type mode clutches typically include a clutch hub driven by the primary driveline, a clutch gear drivingly connected to the secondary driveline, and a mode sleeve coupled for rotation with the clutch hub and which is slidably moveable thereon between first and second mode positions. In the first mode position, the mode sleeve is disengaged from coupled engagement with the clutch gear so as to establish the two-wheel drive mode. In the second mode position, the mode sleeve drivingly couples the clutch gear to the clutch hub so as to establish the four-wheel drive mode. The mode clutch may also include a synchronizer assembly that is operably disposed between the mode sleeve and the clutch gear to facilitate speed synchronization between the clutch hub and the clutch gear prior to complete movement of the mode sleeve into its second mode position.

The mode shift mechanism may further include a power-operated shift actuator for selectively moving the mode sleeve between its first and second mode positions. Such a power-operated shift actuator may include an electric motor driving

2

a rotary-to-linear conversion device which, in turn, is configured to axially translate a shift fork for slidably translating the mode sleeve. A manually-operated mode select device (i.e., lever, push-button, toggle switch, etc.) located in the passenger compartment of the vehicle may be engaged to select between the two-wheel drive mode and the four-wheel drive mode. Upon selection of the desired drive mode, a mode signal is transmitted to a controller for controlling actuation of the electric motor to cause axial translation of the mode sleeve toward the mode position corresponding to the selected drive mode.

However, during an attempted mode shift from the two-wheel drive mode into the four-wheel drive mode, a “blocked” condition may occur between the engagement teeth on the mode sleeve and the clutch teeth on the clutch gear. Typically, a blocked condition exists when the engagement teeth on the mode sleeve are aligned with the clutch teeth on the clutch gear so as to prevent the mode sleeve from moving completely into its second mode position. When such a blocked condition exists, further axial translation of the mode sleeve toward its second mode position may only occur if the clutch gear is rotatably indexed relative to the mode sleeve to eliminate the blocked tooth condition. Accordingly, a significant axial force must be applied through the mode sleeve to the clutch gear to exert an index torque that is adequate to rotatably index the clutch gear relative to the mode sleeve.

Despite the shortcoming noted above, many conventional power transfer devices are equipped with a power-operated mode shift actuator that is only capable of outputting an axial force (generated via the electric motor and the rotary-to-linear conversion device) to the mode sleeve having a magnitude sufficient to complete the 2WD/4WD mode shift during an “unblocked” condition. To overcome blocked conditions, some conventional mode shift mechanisms may incorporate a spring-biasing arrangement configured to normally bias the mode sleeve toward its second mode position and assist in completing the 2WD/4WD mode shift once the tooth block condition has been eliminated due to rolling movement of the vehicle. To address this shortcoming, it has been proposed to increase the magnitude of the axial force transmitted by the power-operated mode shift actuator to the mode sleeve. Unfortunately, such a solution would be undesirably costly and require large mode shift components and high power actuators. Accordingly, a recognized need exists in the industry to provide a reduced effort mode shift mechanism that permits use of smaller and less expensive components and low power actuators while providing an axial force sufficient to overcome most tooth block conditions.

### SUMMARY

This section provides a general summary of the disclosure and is not a comprehensive disclosure of its full scope or all of its features.

It is an aspect of the present disclosure to provide a mode shift mechanism for use in shifting a power transfer device between a two-wheel drive mode and a four-wheel drive mode and which employs a low effort shift operator in conjunction with a sleeve-type mode clutch assembly. The power transfer device is configured to normally transmit drive torque from a powertrain to a primary driveline and to selectively transmit drive torque to a secondary driveline through engagement of the mode clutch assembly.

It is another aspect of the present disclosure to configure and locate the low effort shift operator for reducing the tangential load required to rotatably index a clutch gear relative

3

to a mode sleeve of the mode clutch assembly. The low effort shift operator may be operably disposed between the clutch gear and a component of a transfer mechanism which is drivingly connected to the secondary driveline.

It is a further aspect of the present disclosure to intentionally introduce a predetermined amount of angular play or “backlash” into the mode shift mechanism by providing an additional interface between the clutch gear and the component of the transfer mechanism which is drivingly connected to the secondary driveline.

In accordance with one or more of these aspects, the additional interface can be operably disposed between the clutch gear and a component of the transfer mechanism that is mounted on a first output shaft. The additional interface is configured as a low effort shift operator which may include a spring-loaded cam mechanism that is disposed between the clutch gear and the component of the transfer mechanism. The additional interface noted above can be operably disposed between the clutch gear and a transfer hub that is rotatably mounted on the first output shaft. A first transfer component, such as a first sprocket, is coupled for rotation with the transfer hub and is operable for driving a second transfer component, such as a second sprocket, which is drivingly connected to a second output shaft.

Based on these aspects, the present disclosure provides a power transfer device for a four-wheel drive vehicle which includes a first output shaft for normally transferring torque to a first driveline and a second output shaft for selectively transferring torque to a second driveline. A mode clutch assembly is operable for drivingly connecting the first and second output shafts and may include a clutch hub driven by the first output shaft, a clutch gear, a mode sleeve driven by and axially moveable on the clutch hub relative to the clutch gear, and a low effort shift operator. A transfer mechanism is driven by the second output shaft and includes a transfer component rotatably surrounding the first output shaft. A transfer hub is fixedly connected to the transfer component. The low effort shift operator is disposed between the transfer hub and the clutch gear to permit angular relative movement therebetween during axial movement of the mode sleeve into coupled engagement with the clutch gear. The transfer hub includes external drive teeth that are interdigitated with internal drive teeth formed on the clutch gear and which define a predetermined amount of clearance therebetween. The low effort shift operator includes a cam mechanism that is configured to normally center the interdigitated internal and external drive teeth and facilitate take-up of the clearances therebetween via controlled relative rotation between the clutch gear and the transfer hub which is required to permit complete engagement of mode sleeve with the clutch gear so as to circumvent blocked mode shifts.

A power transfer device for a four-wheel drive vehicle having a first driveline for driving a pair of first wheels and a second driveline for driving a pair of second wheels may include a low effort shift operator configured to facilitate smooth shifting of a mode shift clutch assembly. The power transfer device includes a first shaft driving the first driveline, a second shaft driving the second driveline, and a transfer mechanism drivingly coupled to the second shaft and selectively engageable by the mode clutch assembly to cause the first shaft to drive the second shaft and establish a four-wheel drive mode. The low shift effort operator is associated with an interface connection between the mode clutch and the transfer mechanism and is configured to provide a predefined amount of backlash into the interface to facilitate smooth engagement of the mode shift clutch assembly. The low shift effort operator includes a toothed connection and a spring-

4

biased cam mechanism to maintain the toothed connection in a “centered” orientation. Actuation of the spring-biased cam mechanism permits introduction of the backlash into the toothed connection to circumvent a blocked mode shift when a mode sleeve driven by the first shaft moves into engagement with a clutch gear. The low effort shift operator interconnects the clutch gear to the transfer mechanism.

Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

## DRAWINGS

The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

FIG. 1 is a schematic depicting a four-wheel drive motor vehicle equipped with a power transfer device constructed and operable in accordance with the teachings of the present disclosure;

FIG. 2 is a sectional view taken through an exemplary power transfer device having a mode shift mechanism configured to include a low effort shift operator and a mode clutch assembly that are constructed and operable in accordance with the teachings of the present disclosure;

FIG. 3 is an exploded perspective view of the mode clutch assembly and the low effort shift operator associated with the mode shift mechanism of the power transfer device shown in FIG. 2;

FIG. 4 is an exploded perspective view showing various components of low effort shift operator associated with the mode shift mechanism and the power transfer device of the present disclosure;

FIG. 5 is a fragmentary sectional view of a portion of the power transfer device showing components of the low effort shift operator and the mode clutch assembly;

FIG. 6 is a sectional view taken generally along a different plane than the plane associated with the sectional view of FIG. 5;

FIG. 7 is a sectional view taken generally along line 7-7 as shown in FIG. 5;

FIG. 8 is a sectional view taken generally along line 8-8 as shown in FIG. 5; and

FIG. 9 is a sectional view taken generally along line 9-9 as shown in FIG. 5.

Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

## DETAILED DESCRIPTION

Example embodiments will now be described more fully with reference to the accompanying drawings.

In general, the present disclosure is directed to incorporation of a low effort shift operator into a mode shift system associated with a power transfer device of the type adapted to be installed in a four-wheel drive or all-wheel drive motor vehicle. The low effort shift operator is operable to introduce a predetermined amount of angular clearance, hereinafter referred to as “backlash”, at a preselected component interface within the mode shift system. The low effort shift operator is capable of reducing the tangential load required to index a component of a transfer mechanism relative to an axially moveable mode sleeve associated with a mode clutch assembly so as to inhibit blocked mode shifts. The location, struc-

5

ture and function of the low effort shift operator will now be described in association with an exemplary mode shift system integrated into an exemplary power transfer device of the type used in four-wheel drive vehicles, with particular attention drawn to the following written description in combination with the accompanying drawings.

Referring now to FIG. 1 of the drawings, an exemplary four-wheel drive vehicle 10 is schematically shown to include a front driveline 12, a rear driveline 14 and a powertrain for generating and selectively delivering rotary tractive power (i.e., drive torque) to the drivelines. The powertrain is shown to include an engine 16 and a transmission 18 which may be of either the manual or automatic type. In the particular embodiment shown, vehicle 10 further includes a power transfer device 20 for transmitting drive torque from the powertrain to front driveline 12 and rear driveline 14. In the particular vehicular arrangement shown, power transfer device 20 is configured as a “transfer case”. Front driveline 12 includes a pair of front wheels 22 connected via a front axle assembly 24 and a front propshaft 26 to a front output shaft 30 of transfer case 20. Similarly, rear driveline 14 includes a pair of rear wheels 32 connected via a rear axle assembly 34 and a rear propshaft 36 to a rear output shaft 38 of transfer case 20.

Referring primarily to FIGS. 1 and 2, transfer case 20 is shown to be generally equipped with a two-speed range unit 40, a mode clutch assembly 42, and a power-operated shift actuator 44 that is operable to control coordinated actuation of range unit 40 and mode clutch assembly 42. In addition, a control system 46 is provided for controlling actuation of shift actuator 44. Control system 46 may include one or more vehicle sensors 48 for detecting real time operational characteristics of motor vehicle 10, a mode select mechanism 50 for permitting the vehicle operator to select one of the available drive modes, and an electronic control unit (ECU) 52 that is operable to generate electric control signals in response to sensor signals from sensors 48 and mode signals from mode select mechanism 50.

In accordance with the exemplary drivetrain arrangement shown for vehicle 10, rear output shaft 38 and rear driveline 14 cumulatively define a first or primary driveline that is adapted to normally receive drive torque from the powertrain. Likewise, front output shaft 30 and front driveline 12 cumulatively define a second or secondary driveline that is adapted to only receive drive torque from the powertrain upon engagement of mode clutch assembly 42. Those skilled in the art will recognize and appreciate that the drivetrain arrangement for vehicle 10 could be alternatively arranged with front driveline 12 as the primary driveline and rear driveline 14 as the secondary driveline when power transfer device 20 is configured as a “power take-off unit” and the powertrain is oriented transversely to the longitudinal direction of the vehicle.

Transfer case 20 includes an input shaft 54 that is adapted for driven connection to the output shaft of transmission 18. Input shaft 54 is supported in a housing 56 by a bearing assembly 58 for rotation about a first rotary axis. Rear output shaft 38 is supported between input shaft 54 and housing 56 for rotation about the first rotary axis via a pair of laterally-spaced bearing assemblies 60 and 62. In addition, front output shaft 30 is supported in housing 56 for rotation about a second rotary axis via a pair of bearing assemblies 64 and 66.

Range unit 40 is shown to generally include a planetary gearset 68 and a range clutch 70. Planetary gearset 68 may include a sun gear 72 driven by input shaft 54, a ring gear 74 non-rotatably fixed to housing 56, and a plurality of planet gears 76 rotatably supported from a planet carrier 78. As seen, planet gears 76 are meshed with both sun gear 72 and ring gear 74. Planetary gearset 68 functions to drive planet carrier

6

78 at a reduced speed relative to input shaft 54. Range clutch 70 includes a range collar 80 that is coupled via a splined connection for rotation with and axial sliding movement on a portion of rear output shaft 38. Range collar 80 has external clutch teeth 82 adapted to selectively engage either internal clutch teeth 84 formed on input shaft 54 or internal clutch teeth 86 formed on a carrier ring 87 associated with planet carrier 78. Range collar 80 is shown located in a first or high (H) range position such that its clutch teeth 82 are engaged with clutch teeth 84 on input shaft 54. As such, a direct speed ratio or “high-range” drive connection is established between input shaft 54 and rear output shaft 38. Range collar 80 is axially moveable on rear output shaft 38 from its H range position through a second or neutral (N) position into a third or low (L) range position. Location of range collar 80 in its N position functions to disengage its clutch teeth 82 from both clutch teeth 84 on input shaft 54 and clutch teeth 86 on carrier ring 87, thereby uncoupling rear output shaft 38 from driven connection with input shaft 54. In contrast, movement of range collar 80 into its L range position causes its clutch teeth 82 to engage clutch teeth 86 on carrier ring 87 of planet carrier 78, thereby establishing a reduced speed ratio or “low-range” drive connection between input shaft 54 and rear output shaft 38. Range collar 80 includes an annular groove 81 adapted to receive a range fork 83 associated with power-operated shift actuator 44.

It will be appreciated that planetary gearset 68 and non-synchronized range clutch 70 function to provide transfer case 20 with a two-speed (i.e., high-range and low-range) feature. However, the non-synchronized range clutch 70 disclosed could be easily replaced with a synchronized range clutch to permit “on-the-move” range shifting between the high-range and low-range drive modes without the need to stop the motor vehicle. Furthermore, any two-speed reduction unit having a shift member axially moveable to establish first and second speed ratio drive connections between input shaft 54 and rear output shaft 38 is also considered to be within the scope of this invention. In addition, the teachings of the present disclosure are also applicable to single speed versions of transfer cases 20 wherein rear output shaft 38 is directly coupled to or formed integrally with input shaft 54.

Mode clutch assembly 42 is operable to selectively transfer drive torque from rear output shaft 38 through a transfer mechanism 89 to front output shaft 30. Transfer mechanism 89 may include a transfer hub, hereinafter referred to as a sprocket hub 90, that is supported for rotation on rear output shaft 38. Sprocket hub 90 is fixed via a splined connection for rotation with a first transfer component, hereinafter referred to as drive or first sprocket 92. A second transfer component, hereinafter referred to as driven or second sprocket 94, is fixed via a splined connection for rotation with front output shaft 30. A flexible power transmission member, such as a power chain 96, encircles and drivingly interconnects first sprocket 92 and second sprocket 94. Transfer mechanism 89 may alternatively be configured as a geared arrangement at least including a drive gear rotatably supported on rear output shaft 38 and a driven gear fixed to front output shaft 30. In such an alternative geared transfer arrangement, a transfer hub would be fixed for rotation with the drive gear.

Referring now primarily to FIGS. 3 through 9, mode clutch assembly 42 is shown to generally include a clutch gear 98, a mode collar or sleeve 100, a clutch hub 102, a blocker ring 104, a middle cone 106, an inner cone 108, and a low effort shift operator 110. Clutch hub 102 has an inner cylindrical hub segment 103 formed with internal splines 112 that are in driving engagement with external splines 114 formed on rear output shaft 38. Clutch hub 102 also includes an outer cylin-

drical hub segment **105** formed with a plurality of circumferentially spaced apart slots **115** each in receipt of a strut **116**. Retaining rings **117** maintain a desired axial position of struts **116** relative to a radial web segment **107** of clutch hub **102**. Web segment **107** interconnects inner hub segment **103** to outer hub segment **105** of clutch hub **102**. A plurality of slots **109** formed in web segment **107** are aligned with the plurality of slots **115** formed in outer hub segment **105**. A plurality of elongated longitudinally-extending external lugs or hub teeth **118** are circumferentially spaced apart and formed on an outer peripheral surface of outer hub segment **105** of clutch hub **102**. A snap ring **119** axially locates and retains clutch hub **102** relative to rear output shaft **38**.

Mode sleeve **100** includes a plurality of elongated longitudinally-extending internal lugs or engagement teeth **120** that are in sliding meshed engagement with external hub teeth **118**. As such, mode sleeve **100** is driven by rear output shaft **38**. An annular groove **122** is formed on mode sleeve **100** for receipt of a portion of a mode fork **124** associated with power-operated shift actuator **44**.

Blocker ring **104**, middle cone **106** and inner cone **108** cumulatively define a synchronizer assembly that is operable for facilitating speed synchronization between clutch hub **102** and clutch gear **98**. Inner cone **108** includes an outer conical friction surface **126** and a plurality of axially extending tabs **128** which extend into slots **109** in web segment **107** so as to couple inner cone **108** for rotation with clutch hub **102**. Middle cone **106** includes an inner conical friction surface **130** configured for driving engagement with outer conical surface **126** on inner core **108** and also includes an outer conical friction surface **132**. A plurality of circumferentially spaced apart and axially extending tabs **134** cooperate with slots **136** formed on sprocket hub **90** so as to fix middle cone **106** for rotation with sprocket hub **90**. Slots **136** are each shown to be formed between a pair of raised lugs **137** which extend outwardly from a raised ring segment **153** of sprocket hub **90**. Blocker ring **104** includes a plurality of radially extending tabs **140** which cooperate with struts **116** and slots **115** to allow blocker ring **104** to rotate or circumferentially index only a predetermined amount relative to clutch hub **102**. A plurality of external blocker teeth **142** are formed on blocker ring **104** and are configured to selectively drivingly mesh with internal engagement teeth **120** of mode sleeve **100**. An inner conical friction surface **144** formed on blocker ring **104** is configured for selective driving engagement with outer conical surface **132** on middle cone **106**.

Sprocket hub **90** includes a tubular end segment **146** having external spline teeth **150** that are drivingly engaged with internal spline teeth **151** formed on first sprocket **92**. As such, sprocket hub **90** is coupled to be driven by the secondary driveline via transfer mechanism **89**. Low effort shift operator **110** is operably associated with sprocket hub **90** and clutch gear **98** and includes a plurality of circumferentially spaced apart lugs or external drive teeth **152** which extend radially outwardly from raised ring segment **153** of sprocket hub **90**. A plurality of recesses **154** are provided on raised ring segment **153** of sprocket hub **90** between raised lugs **137** and external drive teeth **152**. Recesses **154** are equally spaced with an exemplary quantity of four (4) shown in the drawings. A radial bore or retention pocket **155** is formed within each recess **154**.

Clutch gear **98** includes a set of elongated and longitudinally-extending external clutch teeth **158** that are sized and shaped for selective driving engagement with engagement teeth **120** of mode sleeve **100**. As part of low effort shift operator **110**, clutch gear **98** also includes a set of lugs or internal drive teeth **160** that are sized and shaped to mate with

external drive teeth **152** on ring segment **153** of sprocket hub **90** with a predetermined amount of “backlash” therebetween that is greater than provided in typical splined or drive gear engagements. In the example depicted in the drawings, an overall amount of backlash of about eight degrees of relative rotation is provided between clutch gear **98** and sprocket hub **90** via the interdigitated meshing of external drive teeth **152** with internal drive teeth **160**. In addition, a plurality of recesses **159** are formed in clutch gear **98** between its internal drive teeth **160** and which are configured to receive raised lugs **137** of sprocket hub **90**. A spacer sleeve **161** is also provided to axially and radially locate and constrain clutch gear **98** relative to sprocket hub **90**. Spacer sleeve **161** generally surrounds an intermediate segment **163** of sprocket hub **90** that is located between end segment **146** and raised ring segment **153**. Sleeve **161** may be connected to first sprocket **92**, but must be configured to permit limited relative rotation between clutch gear **98** and sprocket hub **90** corresponding to the predetermined amount of backlash provided therebetween by low effort shift operator **110**.

Low shift effort operator **110** also includes a spring-biased cam mechanism that is operably disposed between sprocket hub **90** and clutch gear **98**. The spring-biased cam mechanism includes a plurality of “ramped” seats, hereinafter referenced to as ball seats **162**, that are circumferentially spaced apart from one another and formed on clutch gear **98** between pairs of internal drive teeth **160**. Ball seats **162** are adapted to be aligned, upon assembly, with recesses **154** formed in ring segment **153** of sprocket hub **90**. The spring-biased cam mechanism further includes a plurality of followers, such as balls **164**, which are biased into engagement with each ball seat **162** by biasing members, such as coil springs **166**. Springs **166** and balls **164** are at least partially positioned within radial retention pockets **155**. As best shown in FIG. 7, each internal drive tooth **160** formed in clutch gear **98** is centrally disposed between adjacent external drive teeth **152** formed on sprocket hub **90** when balls **164** are centered within the deepest portion of ball seats **162**. Ball seats **162** are configured to be symmetrical and define a pair of ramp surfaces **168**. When a relative (i.e. indexing) torque is applied between sprocket hub **90** and clutch gear **98** in either direction, one of the pair of ramp surfaces **168** associated with each ball seat **162** acts to forcibly urge balls **164** to move radially inwardly in opposition to the biasing of springs **166**. This camming action allows a limited range of relative rotation between clutch gear **98** and sprocket hub **90**. The relative rotation is limited, however, by a positive driving engagement that is established when internal drive teeth **160** on clutch gear **98** physically engage external drive teeth **152** on raised ring segment **153** of sprocket hub **90**. In the example depicted in the drawings, such a positive or direct tooth engagement occurs after about four degrees of relative rotation in either direction.

Mode sleeve **100** is shown in FIGS. 2, 5 and 6 in a first or two-wheel drive mode position so as to place mode clutch assembly **42** in a disengaged condition for operating transfer case **20** in a 2WD mode. Specifically, with mode sleeve **100** in its two-wheel drive mode position, its engagement teeth **120** are displaced from engagement with clutch teeth **158** on clutch gear **98**. As such, first sprocket **92** is not drivingly coupled to rear output shaft **38** such that drive torque is not transmitted through transfer mechanism **89** to front output shaft **30**. In contrast, when mode sleeve **100** is axially moved on clutch hub **102** into a second or four-wheel drive mode position, mode clutch assembly **42** is placed in an engaged condition for operating transfer case **20** in a 4WD mode. Specifically, with mode sleeve **100** in its four-wheel drive

mode position, its engagement teeth **120** are drivingly engaged with clutch teeth **158** on clutch gear **98**. As such, drive torque is transmitted from rear output shaft **38** to drive sprocket **92** through clutch hub **102**, mode sleeve **100**, clutch gear **98** and sprocket hub **90**.

As noted, power-operated shift actuator **44** is provided for controlling movement of range collar **80** between its three distinct range positions and mode sleeve **100** between its two distinct mode positions. Shift actuator **44** includes a power-operated actuation device **200** and a rotary-to-linear conversion mechanism **202**. Actuation device **200** may include an electric motor **204** having a motor output **206** that can be rotated in either direction based on control signals sent to electric motor **204** from controller **52**. Motor output **206** may be connected to a sector plate **208** associated with conversion mechanism **202**. Sector plate **208** may include a range cam surface and a mode cam surface. A range follower **210**, fixed to a range shift assembly **212**, rides along the range cam surface of sector plate **208** to convert rotation of motor output **206** into translational movement of range fork **83**. Likewise, a mode follower **213**, fixed to mode fork **124**, rides along the mode cam surface of sector plate **208** to convert rotation of motor output **206** in translational movement of mode fork **124**. The profiles of the range cam surface and the mode cam surface are configured to coordinate translational movement of range collar **80** and mode sleeve **100** in response to rotation of sector plate **208** for establishing the specific drive mode selected via mode select mechanism **50**. These drive modes may include a two-wheel high-range drive mode, a neutral (i.e. towing) mode, a four-wheel high-range drive mode and a four-wheel low-range drive mode. A rail **214** is shown installed within transfer case **20** for supporting range shift assembly **212** and a tubular section **216** of mode fork **124** for movement thereon. In single-speed versions of power transfer units **20**, range shift assembly **212**, range clutch **70** and planetary gearset **68** are eliminated. It will be understood that any power-operated (or manually-operable) shift actuator **44** can be used to generate and apply an axially-directed bi-directional shift force to mode sleeve **100**.

During operation, if an attempted mode shift from the two-wheel drive mode of operation into the four-wheel drive mode of operation is blocked, engagement teeth **120** on mode sleeve **100** will typically impact clutch teeth **158** of clutch gear **98** after passing through blocker teeth **142** on blocker ring **104**. Each engagement tooth **120** on mode sleeve **100** includes a pointed end having opposing guide faces **172** formed thereon. During such an attempted mode shift, an axial load is applied to mode sleeve **100** via mode fork **124** which is generated by shift actuator **44**. Mode sleeve **100** translates relative to clutch hub **102** and blocker ring **104** as blocker teeth **142** mesh with teeth **120**. At this time, as previously described, full engagement of sleeve teeth **120** with clutch teeth **158** of clutch gear **98** is blocked due to a relative rotational misalignment of the teeth so as to prevent mode sleeve **100** from moving completely into its four-wheel drive mode position. In the past, a relatively large axial force would need to be applied to the mode sleeve **100** to rotate a clutch gear that is directly coupled to or integral with a drive sprocket and its associated driveline components to permit completion of the mode shift. It should be appreciated that this force may be relatively large due to the number of driveline components fixed for rotation with prior versions of the clutch gear. The present arrangement alleviates the need for such a high magnitude application force being applied to mode sleeve **100** through introduction of the intentional backlash made available between internal drive teeth **160** on clutch

gear **98** and external drive teeth **152** on sprocket hub **90** provided by the additional interface associated with low effort shift operator **110**.

More specifically, as an axial load is applied to mode sleeve **100**, guide faces **172** engage front edges of clutch teeth **158** on clutch gear **98**. The tangential load or torque required to rotate clutch gear **98** may be calculated based on the angle of guide faces **172**, the angle of ramp surfaces **168** and the biasing load applied by springs **166**. By design, the torque required to rotate clutch gear **98** and the associated axial force required from mode fork **124** is substantially less than the torque and forces required to rotate driveline components of the prior designs. As such, low effort shift operator **110** permits clutch gear **98** to rotate relative to mode sleeve **100** and sprocket hub **90** until its clutch teeth **158** are properly align with sleeve teeth **120**, thereby allowing mode sleeve **100** to fully translate to its second or four-wheel drive mode position. Once the mode shift has been completed, drive torque is transferred from rear output shaft **38** to first sprocket **92** through clutch hub **102**, mode sleeve **100**, sleeve teeth **120**, clutch gear teeth **158**, drive teeth **160** on clutch gear **98** and drive teeth **152** on sprocket hub **90**. In this way, low effort shift operator **110** provides an additional interface between mode sleeve **100** and clutch gear **98** for introducing limited and controlled backlash therebetween to facilitate smoother mode shifts with reduced axial and tangential load requirements.

In summary, the present disclosure is adapted for use with shift systems using slideable clutch collars or sleeves to address and limit “blocked” tooth engagement conditions between the clutch sleeve and a clutch member such as a clutch gear. Specifically, the present disclosure introduces an additional interface into the mode shift system configured to allow a limited, but predetermined, amount of bi-directional backlash between the clutched components to reduce the effort (i.e. application force) required to establish a fully engaged connection between the clutch sleeve and the clutch gear. The low effort shift operator of the present disclosure provides this additional interface and functions to decrease the tangential load required to circumferentially index the clutch gear from a blocked position into an unblocked position relative to the clutch sleeve. While this additional interface is shown provided by a cam mechanism disposed between the clutch gear and the drive sprocket, those skilled in the art will appreciate that location of the low effort shift operator can be varied within the mode shift system. The cam mechanism is spring loaded to provide a centering function between the components of the low effort shift operator to center the backlash so as to allow indexing in both directions.

What is claimed is:

1. A power transfer device for a four-wheel drive vehicle having a powertrain, a first driveline for driving a pair of first wheels and a second driveline for driving a pair of second wheels, the power transfer device comprising:
  - a first shaft adapted to transmit drive torque from the powertrain to the first driveline;
  - a second shaft adapted to be coupled to the second driveline;
  - a transfer mechanism including a first transfer component rotatably mounted on the first shaft, a second transfer component fixed for rotation with the second shaft, and a transmission component interconnecting the first and second transfer components; and
  - a mode clutch assembly for selectively coupling the first transfer component for driven rotation with the first shaft, the mode clutch assembly including a transfer hub fixed for rotation with the first transfer component, a clutch gear mounted on the transfer hub and having

## 11

clutch teeth, a low shift effort operator providing a predetermined amount of backlash between the transfer hub and the clutch gear, and a mode sleeve fixed for rotation with and axial sliding movement on the first shaft and having engagement teeth, wherein the mode sleeve is operable in a released position to disengage the engagement teeth from the clutch gear teeth for releasing the transfer mechanism from driven connection with the first shaft, and wherein the mode sleeve is operable in an engaged position to engage the engagement teeth with the clutch gear teeth for coupling the transfer mechanism for driven connection with the first shaft;

wherein the low shift effort operator includes a backlash interface connection between the clutch gear and the transfer hub to permit a predetermined amount of angular movement therebetween so as to reduce an axial force required to move the mode sleeve from the released position into the engaged position, the backlash interface connection including external drive teeth formed on the transfer hub, wherein a plurality of recesses are formed between certain adjacent pairs of the external drive teeth with a retention chamber formed in each recess, internal drive teeth formed on the clutch gear and which are interdigitated with the external drive teeth on the transfer hub, wherein a plurality of ramped seats are formed between adjacent pairs of the internal drive teeth and which are aligned with respect to the plurality of recesses, and a plurality of spring-biased followers that are at least partially disposed in the retention chambers and engage a corresponding ramped seat so as to define a predefined amount of angular clearance between each set of interdigitated internal and external drive teeth, and wherein the clutch gear is rotatable through the backlash to align the clutch gear teeth with the mode sleeve engagement teeth to circumvent a blocked movement of the mode sleeve into the engaged position.

2. The power transfer device of claim 1, wherein the predetermined amount of backlash is about eight degrees of relative rotation between the transfer hub and the clutch gear.

3. The power transfer device of claim 1 wherein the first transfer component is a first sprocket, the second transfer component is a second sprocket, and the transmission component is a belt or chain interconnecting the first sprocket for rotation with the second sprocket.

4. The power transfer device of claim 3 wherein the transfer hub is a sprocket hub fixed for rotation with the first sprocket and rotatably surrounding the first shaft, wherein the transfer hub includes a ring segment from which the external drive teeth extend and in which the recesses are formed, and wherein the clutch gear generally surrounds the ring segment of the transfer hub such that the internal drive teeth are meshed with the external drive teeth and the ramped seats are aligned with the recesses.

5. The power transfer device of claim 4 wherein the spring-biased followers include a coil spring and a ball partially retained in each of the recesses, and wherein each ball is biased into engagement with a central portion of a corresponding one of the ramped seats to centrally locate and align the internal drive teeth of the clutch gear relative to the external drive teeth on the ring segment of the sprocket hub.

6. The power transfer device of claim 5 wherein each of the ramped seats includes a pair of ramp cam surfaces configured to displace the balls inwardly against a biasing force of the coil springs in response to rotational movement of the clutch

## 12

gear relative to the sprocket hub in response to translational movement of the mode sleeve from the released position into its engaged position.

7. The power transfer device of claim 1 wherein the mode clutch assembly further includes a synchronizer that is operably disposed between the mode sleeve and the clutch gear.

8. The power transfer device of claim 1 further comprising a power-operated actuator operable for moving the mode sleeve between the released and engaged positions, a mode select mechanism for permitting a vehicle operator to select between a two-wheel drive mode established when the mode sleeve is in the released position and a four-wheel drive mode established when the mode sleeve is in the engaged position, and a controller for receiving a mode signal from the mode select mechanism indicative of the selected drive mode and controlling operation of the power-operated actuator in response to the mode signal.

9. The power transfer device of claim 1 wherein the drive torque is transmitted from the first shaft to the first transfer component of the transfer mechanism when the mode sleeve is in the engaged position through engagement of the mode sleeve engagement teeth with the clutch gear teeth and engagement of the internal drive teeth on the clutch gear with the external drive teeth on the transfer hub.

10. A power transfer mechanism for a four-wheel drive vehicle having a powertrain, a first driveline for driving a pair of first wheels and a second driveline for driving a pair of second wheels, comprising:

a first shaft adapted to transmit drive torque from the powertrain to the first driveline;

a second shaft adapted to be coupled to the second driveline;

a transfer mechanism including a first sprocket rotatably mounted on the first shaft, a second sprocket fixed to the second shaft, and a transmission member encircling and interconnecting the first sprocket to the second sprocket;

a mode clutch assembly for selectively coupling the first sprocket for driven rotation with the first shaft, the mode clutch assembly including a clutch gear having clutch gear teeth, a clutch hub driven by the first shaft, and a mode sleeve mounted for rotation with and translational movements on the clutch hub and having mode sleeve teeth, wherein the mode sleeve is operable in a released position to disengage the mode sleeve teeth from the clutch gear teeth for releasing the transfer mechanism from driven connection with the first shaft, and wherein the mode sleeve is operable in an engaged position to engage the mode sleeve teeth with the clutch gear teeth for coupling the transfer mechanism for driven connection with the first shaft; and

a backlash interface connection provided between the first sprocket and the clutch gear to permit a predetermined amount of angular movement therebetween so as to reduce an axial force required to move the mode sleeve from the released position into the engaged position, the backlash interface connection including external drive teeth formed on a sprocket hub fixed for rotation with the first sprocket, a plurality of recesses being formed between certain adjacent pairs of the external drive teeth with a retention chamber formed in each recess, internal drive teeth formed in the clutch gear and which are interdigitated with the external drive teeth on sprocket hub, a plurality of ramped seats being formed between adjacent pairs of the internal drive teeth and which are aligned with respect to the plurality of recesses, and a plurality of spring-biased followers at least partially disposed in the retention chambers and engaging a corre-

## 13

sponding ramped seat so as to define a predefined amount of angular clearance between the interdigitated external drive teeth and internal drive teeth to define a predetermined amount of backlash between the first sprocket and the clutch gear, wherein the clutch gear is rotatable through the backlash to align the clutch gear teeth with the mode sleeve teeth to circumvent a blocked movement of the mode sleeve into the engaged position.

11. The power transfer mechanism of claim 10, wherein the predetermined amount of backlash is about eight degrees of relative rotation between the clutch gear and the first sprocket.

12. The power transfer mechanism of claim 10 wherein the sprocket hub is rotatably mounted on the first shaft and includes a first segment to which the first sprocket is fixed for rotation, and a second segment from which the external drive teeth extend and within which the retention chambers are formed.

13. The power transfer mechanism of claim 12 wherein the clutch gear is arranged to surround the second segment of the sprocket hub such that the internal drive teeth are meshed with the external drive teeth and the ramped seats are aligned with the recesses.

14. The power transfer mechanism of claim 13 wherein the spring-biased followers include a coil spring and a ball partially retained in each of the recesses, and wherein each ball is biased into engagement with a central portion of a corresponding one of the ramped seats to centrally locate and align the internal drive teeth of the clutch gear relative to the external drive teeth on the second segment of the sprocket hub.

15. The power mechanism device of claim 14 wherein each of the ramped seats includes a pair of ramp cam surfaces configured to displace the balls inwardly against a biasing force of the coil springs in response to rotational movement of the clutch gear relative to the sprocket hub in response to translational movement of the mode sleeve from the released position into the engaged position.

16. The power transfer mechanism of claim 10 wherein the mode clutch assembly further includes a synchronizer that is operably disposed between the mode sleeve and the clutch gear.

17. The power transfer mechanism of claim 10 further comprising a power-operated actuator operable for moving the mode sleeve between the released and engaged positions, a mode select mechanism for permitting a vehicle operator to select between a two-wheel drive mode established when the mode sleeve is in the released position and a four-wheel drive mode established when the mode sleeve is in the engaged position, and a controller for receiving a mode signal from the mode select mechanism indicative of the selected drive mode and controlling operation of the power-operated actuator in response to the mode signal.

18. The power transfer mechanism of claim 10 wherein the drive torque is transmitted from the first shaft to the first sprocket of the transfer mechanism when the mode sleeve is in the engaged position through engagement of the mode sleeve teeth with the clutch gear teeth and engagement of the internal drive teeth on the clutch gear with the external drive teeth on the sprocket hub.

19. A power transfer device for a motor vehicle having a powertrain, a first driveline driving a pair of first wheels and a second driveline driving a pair of second wheels, the power transfer device comprising:

- a first rotary member adapted to transmit drive torque from the powertrain to the first driveline;
- a second rotary member adapted to be coupled to the second driveline;

## 14

a transfer mechanism including a first transfer component rotatably mounted on the first rotary member and a second transfer component coupled for rotation with the second rotary member and being driven by the first transfer component; and

a mode clutch assembly for selectively coupling the first transfer component to the first rotary member for transmitting drive torque to the second driveline, the mode clutch assembly including a transfer hub driven by the first transfer component, a clutch component mounted on the transfer hub and having clutch teeth, a low shift effort operator disposed between the clutch component and the transfer hub for establishing a backlash interface connection therebetween, and a moveable mode sleeve driven by the first rotary member and having engagement teeth, the mode sleeve being operable in a released position to disengage the engagement teeth from engagement with the clutch teeth on the clutch component for releasing the transfer mechanism from driven connection with the first rotary member, the mode sleeve also being operable in an engaged position to engage the engagement teeth with the clutch teeth on the clutch component for establishing the driven connection between the transfer mechanism and the first rotary member, the backlash interface connection being configured to permit a predetermined amount of angular movement between the clutch component and the transfer hub so as to reduce a force required to move the mode sleeve from the released position into the engaged position;

wherein the backlash interface connection comprises:

external drive teeth formed on the transfer hub and having a recess formed between a pair of the external drive teeth;

internal drive teeth formed on the clutch component which are interdigitated with the external drive teeth and having a cam surface formed between a pair of the internal drive teeth, the cam surface being aligned with the recess;

and a spring-biased cam follower disposed between the recess and the cam surface and which normally engages a central portion of the cam surface to define a predetermined amount of angular clearance between adjacent sets of interdigitated internal and external drive teeth so as to permit limited angular movement of the clutch component relative to the transfer hub to facilitate alignment of the clutch teeth with the engagement teeth.

20. The power transfer device of claim 19 wherein the first transfer component is a first sprocket rotatably mounted on the first rotary member and the second transfer component is a second sprocket fixedly mounted for rotation with the second rotary member, wherein the transfer mechanism further includes a torque transmission component interconnecting the first sprocket to the second sprocket, wherein the transfer hub extends axially from the first sprocket and includes a ring segment from which the external drive teeth extend and on which a plurality of the recesses are formed, and wherein the clutch component is a clutch gear configured to surround the ring segment of the transfer hub such that the internal drive teeth are interdigitated with the external drive teeth and having a plurality of the cam surfaces that are aligned with the plurality of recesses.

21. The power transfer device of claim 19 wherein the mode clutch assembly further includes a clutch hub fixed for rotation with the first rotary member and having axially-extending external splines that are in meshed engagement



## 15

with internal splines on the mode sleeve to facilitate sliding axial movement of the mode sleeve on the clutch hub between the released and engaged positions, and a synchronizer operably disposed between the mode sleeve and the clutch component to facilitate speed synchronization therebetween upon movement of mode sleeve toward the engaged position. 5

22. A power transfer mechanism for a motor vehicle having a powertrain transmitting drive torque to a first driveline for driving a pair of first wheels and a second driveline driving a pair of second wheels, the power transfer mechanism comprising: 10

- a first rotary member adapted to receive drive torque from the powertrain;
- a second rotary member adapted to transmit drive torque to the second driveline; 15
- a transfer assembly coupled for rotation with the second rotary member and having a transfer component rotatably mounted on the first rotary member; and
- a mode clutch assembly operable for selectively coupling the transfer component to the first rotary member for transmitting drive torque through the transfer assembly to the second rotary member, the mode clutch assembly including a clutch component mounted on a hub segment of the transfer component, a low shift effort operator operable for establishing a backlash interface connection between the clutch component and the hub 20 25

## 16

segment, and a mode sleeve driven by the first rotary member and axially moveable relative to the clutch component between first and second positions, wherein the mode sleeve is operable in the first position to be released from coupled engagement with the clutch component and is further operable in the second position to be in coupled engagement with the clutch component, and wherein the backlash interface connection associated with the low effort shift operator is configured to permit a predetermined amount of angular movement of the clutch component relative to the hub segment to reduce the force required to move the mode sleeve from the first position into the second position, the backlash interface connection including internal drive teeth formed on the clutch component which are interdigitated with external drive teeth formed on the hub segment of the transfer component and a spring-biased cam mechanism operable to normally establish a predefined amount of angular clearance between the interdigitated external and internal drive teeth so as to define a predetermined amount of backlash between the clutch component and the transfer component, whereby the clutch component is rotatable through the backlash in response to movement of the mode sleeve from the first position into its second position.

\* \* \* \* \*